Land- ocean contrast and the seasonal to decadal variability of the Northern Hemisphere Jet Stream

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Regional differences in the Northern Hemisphere jet stream latitude and speed are seen on seasonal to decadal timescales based on Twentieth Century Reanalysis dataset (20CR) 1871-2011.

Motivation.

To provide a regional (Land/Ocean) Northern Hemisphere jet stream analysis using one method to define the jet stream, and the 20CR reanalysis data from 1871-2011, the longest available dataset (Compo et al., 2011).

Methodology.

Jet speed was defined as the maximum absolute wind speed $\overline{U}$, based on the 250mb 6-hourly zonal and meridional wind velocity at each longitude (2° resolution).

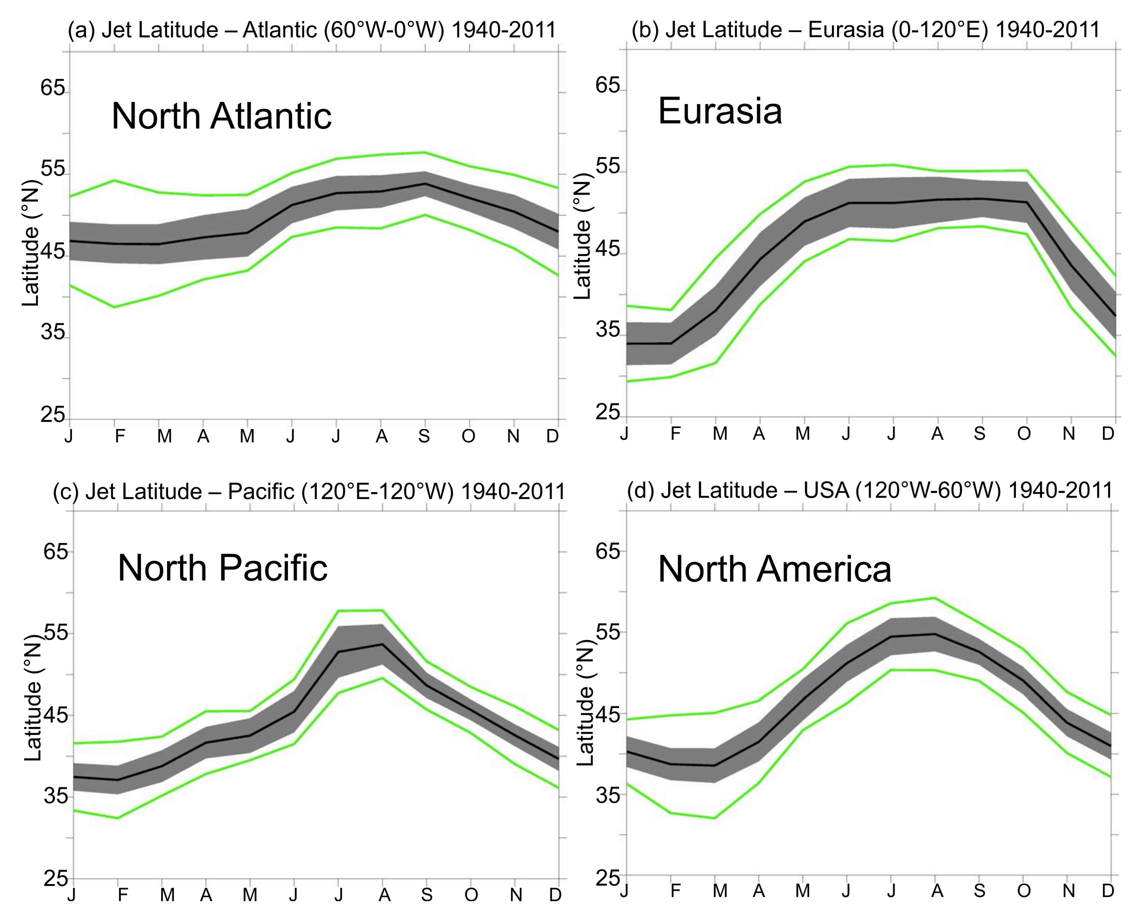
$$\overline{U} = \frac{1}{n}\sum_{i=1}^{i=n}(u_i^2 + v_i^2)^{0.5}$$

where i = 1…56 ensemble members.

Jet latitude was defined as the latitude of maximum jet speed.

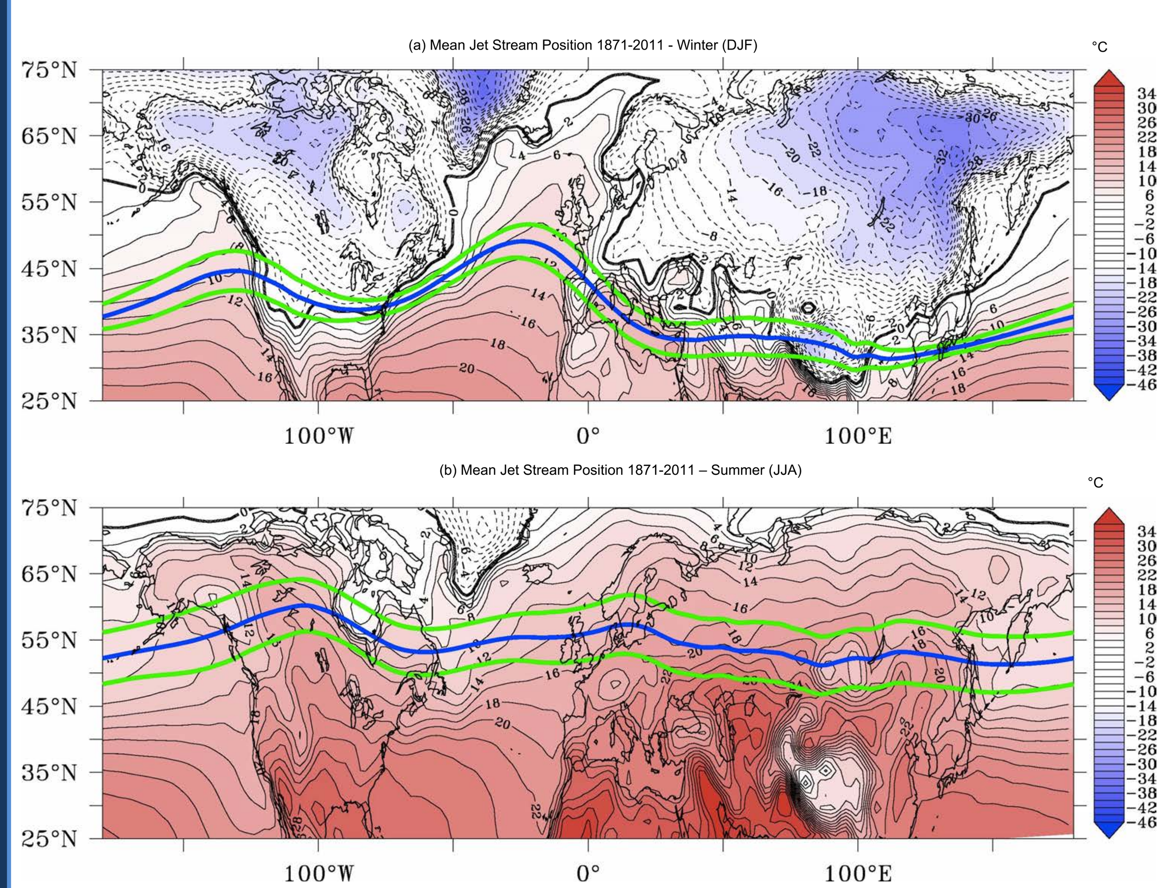
Results

Seasonal Jet Latitude Variability



Seasonally the jet latitude range is lower over the oceans compared to land from 20° over Eurasia to 10° over the North Atlantic where the ocean meridional heat transport is greatest.

Fig. 1 Seasonal Cycle of the jet stream latitude in the Northern Hemisphere by region for periods 1940-2011. Black line is mean jet latitude. Grey area is ± 2 standard deviations smoothed over 31 days based on the 56 ensemble members. Green line is ±2 standard deviations based on the interannual variability for the period



The mean jet latitude range is at a minimum in winter (DJF) particularly along the western boundary of the North Atlantic and North Pacific, where the land-ocean contrast and SST gradients are strongest.

Fig 2. Mean Seasonal Jet Stream Position overlaying the 2 m air temperature for the period 1871 -2011. The dark blue line indicates the mean jet stream position and the green line ± 2 standard deviations of the 6 hourly jet latitude smoothed over 91 days, for the period shown, based on the 56 ensemble members. The cyan blue line is ±2 standard deviations based on the interannual variability for the period

Decadal Trends

Jet Latitude / Jet Speed

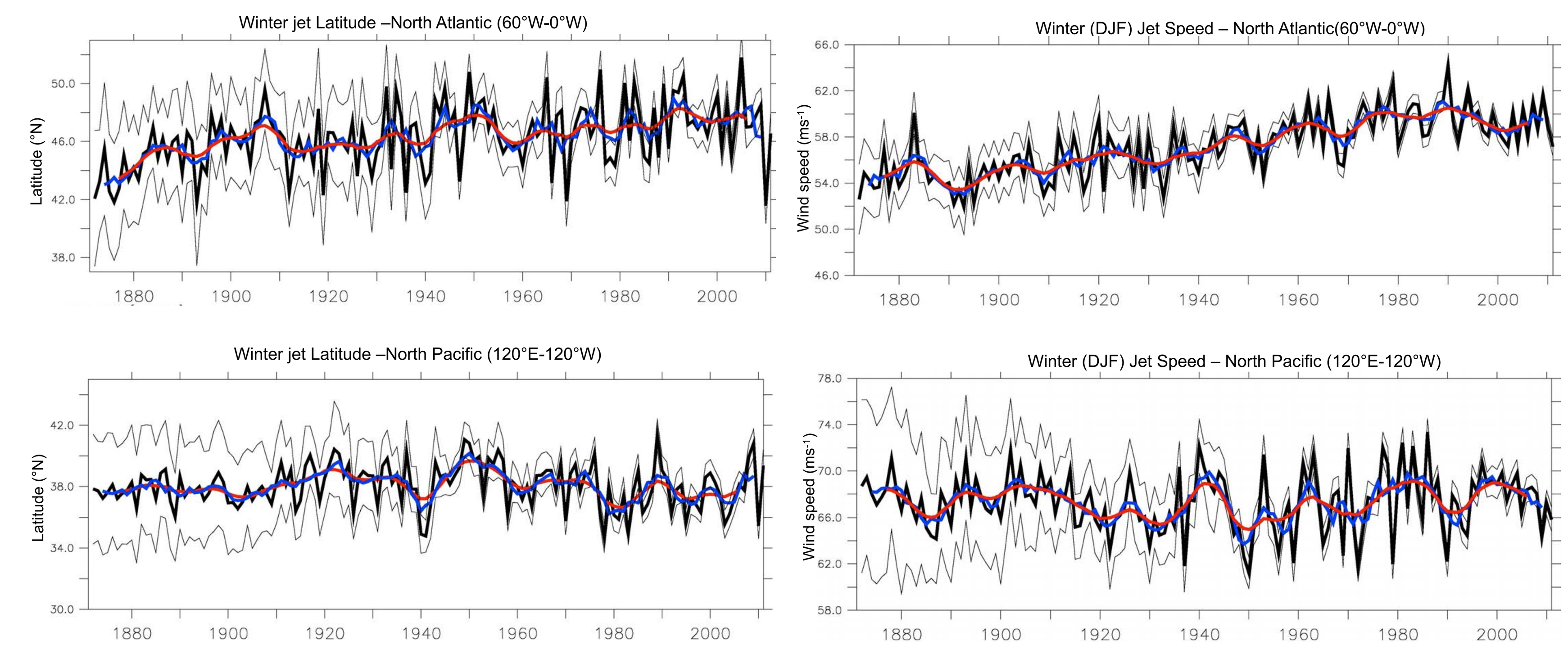


Fig 3. Winter Jet Latitude and speed for North Atlantic and North Pacific from 1871 -2011. The thick black line indicates the seasonal mean. The red line indicates the seasonal mean smoothed over 11 years. The blue line indicates the 5-year running mean. The thin black lines indicate ±2 standard deviations based on the 6 hourly data for the 56 ensemble members smoothed over 91 days

- Significant increases in jet latitude are seen in all seasons in the North Atlantic with an increase of 3°N (0.2°/decade) in winter. The increase in jet latitude is consistent with the decreasing temperature gradient between the pole and equator at the tropopause.
- No significant changes in jet latitude are seen over the North Pacific.
- Significant increases in jet speed are found in all seasons over the North Atlantic up to 4.5ms^{-1}(0.3ms-1/decade) in winter. The increases in jet speed are consistent with the increased 300mb geopotential height gradient between the poles and the equator.
- The North Pacific region has no significant change in jet speed.

Interannual Variability

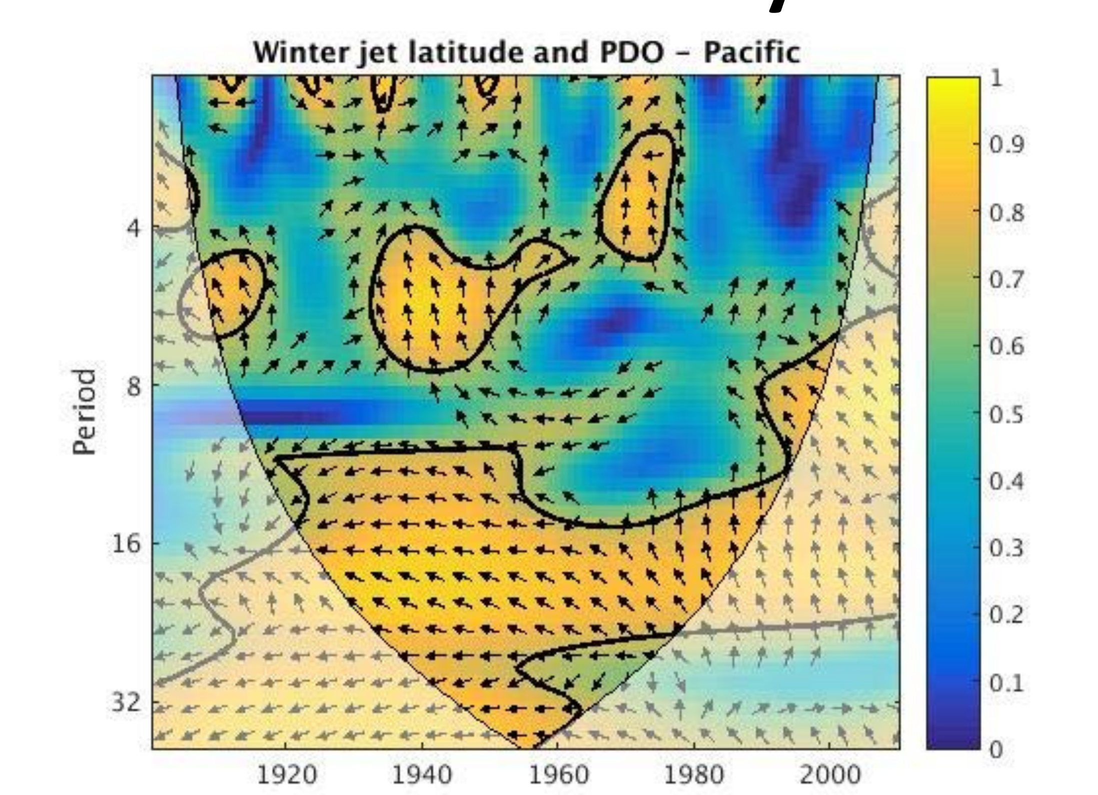


Fig. 4 Wavelet coherence for Jet Latitude for the North Pacific. Colour bar indicates correlation. Black contours indicate statistically significant features (95% confidence level)

In the North Pacific 20-year variability in jet latitude and jet speed are seen (Fig. 4), associated with the Pacific Decadal Oscillation (PDO) which explains 50% of the winter variance in jet latitude since 1940.

The direction of the arrows indicates the PDO and jet stream are anti correlated, and the PDO leads.

+PDO (-PDO) phase leads to increase (decrease) in meridional temp gradient, with warm (cold) anomaly south and cold (warm) anomaly north, associated with a southward (northward) shift in jet stream

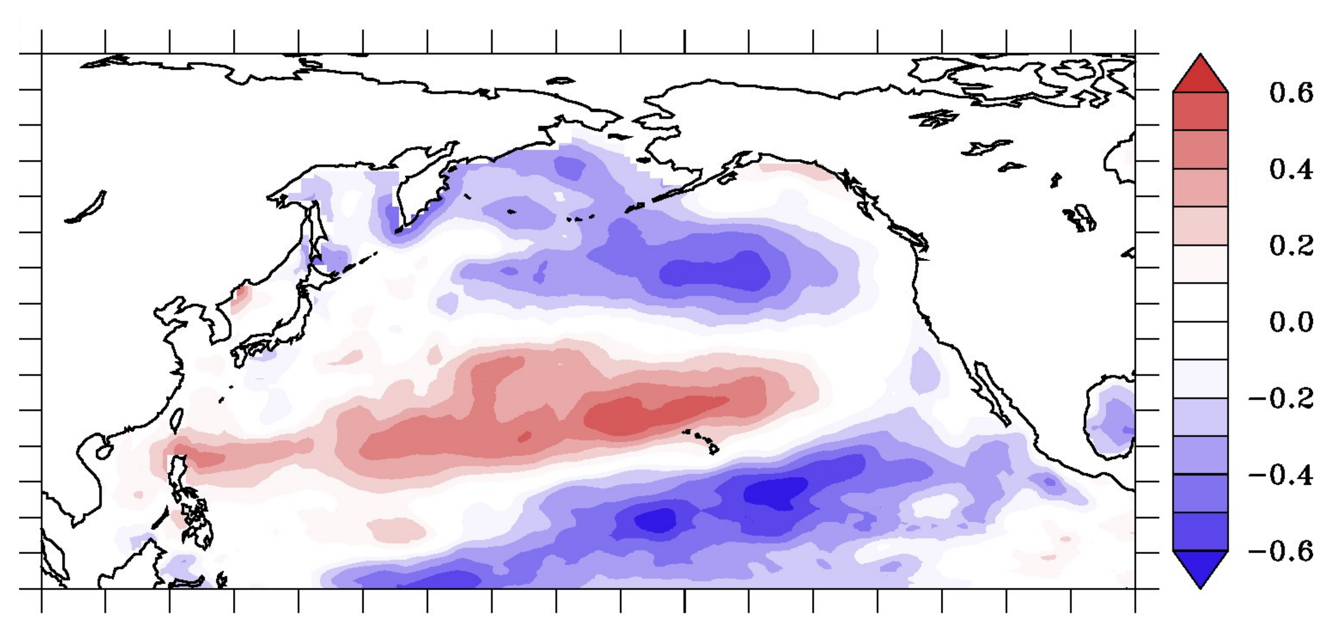


Fig 5. Correlation between winter (DJF) jet stream over the North Pacific and preceding April SSTA anomaly 1980 – 2011

Summary and ongoing work: Regional (land-ocean) differences in jet latitude and speed are seen from seasonal to decadal timescales, with increasing trends in jet latitude and jet speed over the North Atlantic but not over the North Pacific. Over the North Pacific jet latitude and speed variability is associated with PDO variability. Ongoing work as part of the ROADMAP project is looking to understand in more detail how ocean variability in the North Atlantic and North Pacific modulates jet stream behaviour.

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Further reading: Hallam S, Josey SA, McCarthy G, Hirschi JJM (2022) A regional(land-ocean) comparison of the seasonal to decadal variability of the Northern Hemisphere jet stream. Climate Dynamics (accepted) pre-print DOI: https://doi.org/10.21203/rs.3.rs-607067/v1